The influence of final conditions on meat colour in light lamb carcasses

Maria J. Alcaldea,*, Angel I. Negueruelab

aDepartamento Ciencias Agroforestales, Area Producción Animal, Escuela Universitaria Ingeniería Técnica Agrícola, Universidad de Sevilla, Ctra Utrera Km.1, 41013 Seville, Spain
bDepartamento Física Aplicada, Facultad de Veterinaria, Universidad de Zaragoza, C/Miguel Servet, 177, 50.013 Zaragoza, Spain

Received 4 September 1996; received in revised form 17 March 2000; accepted 27 March 2000

Abstract

Tristimulus values \((X, Y, Z)\) and CIELAB colourimetric coordinates have been measured in m. Longissimus dorsi and m. Triceps braquialis caput longum muscles in 86 light carcasses of lambs from different origins. By applying to these data different mathematical methods (ANOVA, Discriminant Analysis, Principal Components Analysis and Cluster Analysis) we have obtained a good classification of these animals in groups, which has been established according to the different final conditions (feeding or storage). In this way, the percentage of animals accurately classified into their group is 94.2%. Worse results were obtained (84.9%) if the animals were grouped taking their breed or/and origin as a reference. © 2000 Elsevier Science Ltd. All rights reserved.

1. Introduction

Quality or “fitness for purpose” is necessary for economic competition, and no production problem can be undertaken without considering this crucial aspect. Although there are subjective estimating characteristics, however, it is possible to objectively measure some of them.

The visual appearance of the meat products is an essential factor, according to which the consumers judge their acceptance (Clydesdale, 1991). In this way, the meat pieces are selected for their leaniness, their general appearance and their colour. This last aspect is used as an indicator of the flavor, tenderness and freshness of the purchase (Naumann, Rhodes, Brady & Kiehl, 1957).

In Mediterranean countries, like Spain, light colour is associated with the meat of young animals, which is preferred, having a great influence on the price (Colomer, 1978). On the other hand, there are other countries where darker meat is more easily accepted.

In this paper, we have used light lamb carcasses, whose weight rank was established between 9.5 and 12 kg. It is also known that even within the same slaughter weight there are many factors that influence the colour:

- Biological: muscle type (Monin, 1989), breed (Boccard, Valin & Bonaiti, 1980), age (Sierra, 1974).
- Extrinsic: feeding–breeding system (Rhodes, 1971; Sañudo, Sierra, Olleta, Conesa & Alcalde, 1989), the use of growth stimulators (Beermann, Fishell, Hogue & Dalrymple, 1985).
- Physico–chemical: pH (Faustman & Cassens, 1990), temperature (Renerre, 1987), electric shock (Moore & Young, 1991; Riley, Savell, Smith & Shelton, 1980), storage (Moore, 1990), etc.

Different statistical analyses have been applied, with the aim of finding the highest discriminatory power within the different types of lamb carcasses that are considered in a determined weight rank. Another quality meat variables (sensory valuation, water holding capacity, pH, pigments by Hornsey method, toughness by Warner Braztler) have been tested with the same
animals (unpublished data by the authors), but none of them has managed to discriminate accurately more than 40% of the animals. On the other hand, a high discrimination capacity has been obtained by colourimetric variables (Alcalde, Negueruela, Sañudo & Sierra, 1993).

2. Materials and Methods

2.1. Animals

Eighty-six lamb carcasses (9.5–12 kg) from male animals were used to carry out this work, belonging to the following groups:

1. Twenty-seven from animals of Rasa Aragonesa (R.A.) breed. These animals were weaned with an average age of 46 days, and after fed on cereal straw and concentrate ad libitum until slaughter at 70–90 days old.
2. Eight Spanish Merina (S.M.) animals. Lambs were reared in an extensive regime until 60 days old and later stabled and fed on concentrate and straw (in a similar way as Rasa animals) and slaughtered at 80–90 days old.
3. Six from Manchega (M.) animals. Lambs weaned at 50 days old and fed in a similar form to Rasa animals, until slaughter at 70–80 days old.
4. Eight refrigerated British carcasses (R.B.), kept on an extensive feeding system (pasture) and slaughtered at 5–6 months old. The refrigerated carcasses were imported from UK.
5. Eight frozen thawed New Zealander carcasses (F.NZ.). Reared on an extensive feeding system, slaughtered at 5–6 months old and imported frozen from NZ. They were thawed in Spain.
6. Seven Argentinian carcasses (F.A.). Under similar conditions (reared in system, age) to the New Zealander ones. They also were imported frozen from Argentina and thawed in Spain.
7. Seven from suckling Lacaunes (S.L.), slaughtered in Spain at 60–70 days old, immediately after being imported from farms from the South of France.
8. Eight from German Merinos (G.M.), imported live, coming from an extensive feeding system in Germany and finished (final period of feeding) in Spain in a feed-lot system and slaughtered at 80–90 days old.
9. Seven from weaned Lacaunes (W.L.), also from the South of France. Because of their lower weight, they were finished in Spain with concentrate and straw and slaughtered at 65–80 days old.

When groups 8 and 9 came to Spain they were fed in the same stable under the same feed-lot conditions.

2.2. Methodology

The colourimetric parameters were measured with a reflectometer-colourimeter (Minolta CR-200b) using two colour spaces for the representation: \(X\), \(Y\), \(Z\) values and CIELAB (Commission Internationale de L'Eclairage [CIE], 1986). Standard illuminant C and \(2^\circ\) standard observer CIE 31 were used for all measurements.

The measurements were taken 96 h after the slaughter in groups 1, 2, 3, 7, 8 and 9. British carcasses (group 4) had a six-day period of ageing, because of the transport from U.K., until taking the measurements. The frozen carcasses (New Zealander and Argentinian carcasses, groups 5 and 6 respectively) were thawed 48 h previously the measurements were taken. The carcasses were kept refrigerated during these periods of 96 h, six days and 48 h respectively.

The measurement were made in three sites. Site 1 and site 2 in m. Triceps braqui caput longum (we called it as I.TB) and in m. Longissimus dorsi thoraci (I.LD) respectively, where the measures were taken internally immediately after cutting the muscle before blooming was set, and site 3 on the surface part of the m. Longissimus dorsi thoraci (S.LD) after blooming for 24 h. Three repetitions were taken in each site and the mean was calculated.

2.3. Statistical analysis

Packet Systat (1992), for Windows has been used for the statistical analysis and four methods have been considered: One-way Anova and contrasted with LSD, multivariate discriminant analysis, principal components analysis, and cluster analysis (a simple linkage had been used).

The purpose of this paper is to find differences between carcasses groups through the use of colour as the criteria to discriminate the origin, the production system and the final conditions of the animals in spite of not knowing them accurately sometimes.

3. Results and discussion

3.1. Analysis by groups

3.1.1. ANOVA

Within the three measurement sites (I.LD, I.TB and S.LD), there were significant differences between groups. The Lightness (\(L^*\)) of the CIELAB space at the three sites of measurement shows large differences \((P<0.001)\) between the groups, the sucking and weaned Lacaune and German Merino carcasses having the lightest meat. There were no differences between Spanish groups (Rasa Aragonesa, Merina and Manchega). British,
Argentinian and New Zealander carcasses have the darkest meat.

3.1.2. Discriminant analysis

Many tests have been made with a different number of variables at the different measurement sites (I.LD, S.LD and I.TB). Percentages of correct assignments can be observed in Table 1, for the different cases.

The discrimination is better when increasing the sites of measurement with the same variables than when increasing the number of variables in a site. In this way, the best discrimination (84.9%) is obtained using all the variables (X, Y, Z, L*, a*, b*) at the three sites.

When we consider all the analyses carried out, we can state:

- Frozen–thawed carcasses are easily discriminated and, in the worst situation (analyses made when we consider less variables and/or less sites of measurements), they appeared mixed with refrigerated British carcasses. Also in these analyses, most of the refrigerated British carcasses are classified into their correct group but some of them are included within the frozen carcass groups.
- Some carcasses of the Rasa, Manchega and Spanish Merino groups are often mixed up together, and sometimes with the refrigerated British carcasses group.
- Carcasses of weaned Lacaune and German Merino are mixed in spite of having a very different genotype and a different initial rearing system, but, as we said before, they had the same final feeding conditions. Some individuals of Rasa, who come from the same final feeding place as these two groups, are included, in some analyses, in one of these two groups.

Moreover, the statistical program gives us information about the group to which an animal is assigned in each classification. We can study if discrimination errors (animals that the statistical method have classified out of their real group) occur at random or they are systematic with a possible reason that can explain it. In this way, we have been able to check that the animals are not incorrectly classified at random: some animals are systematically classified inaccurately but always in the same group; the classification of other animals fluctuates always between two groups; in both cases (inaccurate classification and fluctuation between groups) the reason can be the similar production features (type of feed-lot, age, storage, etc.) of these different groups with the real group.

---

**Table 1**
Correct discrimination percentage for the lamb groups by means of the colour variables in the different measurements sites

<table>
<thead>
<tr>
<th></th>
<th>XYZ</th>
<th>L*,a*,b*</th>
<th>XYZL*,a*,b*</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.TB*</td>
<td>53.5</td>
<td>53.5</td>
<td>53.5</td>
</tr>
<tr>
<td>I.LD*</td>
<td>48.8</td>
<td>48.8</td>
<td>57.0</td>
</tr>
<tr>
<td>s.LD*</td>
<td>48.8</td>
<td>47.7</td>
<td>50.0</td>
</tr>
<tr>
<td>I.TB*1.LD</td>
<td>64.1</td>
<td>66.3</td>
<td>73.3</td>
</tr>
<tr>
<td>I.TB*1.SLD</td>
<td>67.1</td>
<td>61.6</td>
<td>69.8</td>
</tr>
<tr>
<td>I.LD*1.SLD</td>
<td>59.3</td>
<td>59.6</td>
<td>61.3</td>
</tr>
<tr>
<td>I.TB<em>1.LD</em>1.SLD</td>
<td>75.0</td>
<td>72.1</td>
<td>84.9</td>
</tr>
</tbody>
</table>

---

*a* I.TB: internal measurement in m. Triceps braquialis.
*b* I.LD and S.LD: internal and surface measurements in m. Longissimus dorsi.

**Table 2**
Discriminant analysis frequencies. Classification by carcass groups: assigned (columns) against real data (rows)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>3</td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>8</td>
<td>8</td>
<td>27</td>
</tr>
<tr>
<td>1</td>
<td>6</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td>6</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7</td>
<td>1</td>
<td>8</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>6</td>
<td></td>
<td>7</td>
<td></td>
<td>17</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>Total</td>
<td>26</td>
<td>9</td>
<td>4</td>
<td>8</td>
<td>8</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>86</td>
</tr>
</tbody>
</table>

---

*a* Variables: X,Y,Z,L*,a*,b*, in I.TB (internal measurements in m. Triceps braquialis), S.LD and I.LD (surface and internal measurements in m. Longissimus dorsi).
*b* R.A.: Rasa Argonesa.
*c* S.M.: Spanish Merino.
*d* M.: Manchega.
*e* R.B.: Refrigerated British.
*g* F.A.: Frozen–thawed Argentinian.
*h* S.L.: Suckling Lacaune.
*i* G.M.: German Merino.
*j* W.L.: Weaned Lacaune.
The results obtained with the best discrimination are presented in Table 2. Most of the animals are in the diagonal, so this indicates that there is success between animals assigned into groups by the statistical method and the real grouping of the animals—therefore few animals are placed out of the diagonal in Table 2, as is desirable.

3.1.3. Cluster analysis

This analysis has been made with average values of the colourimetric parameters for each group, but not with the individuals. As can be observed in Fig. 1, closeness among these types is proved. This analysis coincides with the previous explanations about the “relative” wrong classification of some animals (animals classified into other groups with similar production features). Argentinians and New Zealanders are grouped with refrigerated British carcasses. Spanish Merinos are put together with Rasos and afterwards with Manchegos. German Merinos and weaned Lacaunes, together with suckling Lacaunes, are very close to each other. These three groups in turn are also close to the Spanish carcass group.

These explanations show that the final conditions of those animals are a very important discriminate factor. Therefore, it may be advisable to make a new discriminant analysis grouping the carcasses, according to this viewpoint, in blocks.

3.2. Statistical analysis according to the final conditions (feeding or storage):

- Block one: Spanish carcasses with similar final feed-lot: Rasa Aragonesa, Spanish Merina and Manchega.
- Block two: refrigerated British carcasses.
- Block three: frozen–thawed carcasses (New Zealanders and Argentinians).
- Block four: carcasses of suckling Lacaunes.

### Table 3

ANOVA, significant differences and average values of the different colour variables grouped in five blocks carcasses made according to the final conditions

<table>
<thead>
<tr>
<th></th>
<th>1&lt;sup&gt;a&lt;/sup&gt;</th>
<th>2&lt;sup&gt;b&lt;/sup&gt;</th>
<th>3&lt;sup&gt;c&lt;/sup&gt;</th>
<th>4&lt;sup&gt;d&lt;/sup&gt;</th>
<th>5&lt;sup&gt;e&lt;/sup&gt;</th>
<th>F&lt;sup&gt;f&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.TB</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>19.96&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>14.70&lt;sup&gt;a&lt;/sup&gt;</td>
<td>14.64&lt;sup&gt;a&lt;/sup&gt;</td>
<td>20.74&lt;sup&gt;b&lt;/sup&gt;</td>
<td>20.76&lt;sup&gt;b&lt;/sup&gt;</td>
<td>***&lt;sup&gt;g&lt;/sup&gt;</td>
</tr>
<tr>
<td>Y</td>
<td>17.11&lt;sup&gt;b&lt;/sup&gt;</td>
<td>12.13&lt;sup&gt;a&lt;/sup&gt;</td>
<td>11.97&lt;sup&gt;a&lt;/sup&gt;</td>
<td>18.01&lt;sup&gt;b&lt;/sup&gt;</td>
<td>17.99&lt;sup&gt;b&lt;/sup&gt;</td>
<td>***&lt;sup&gt;g&lt;/sup&gt;</td>
</tr>
<tr>
<td>Z</td>
<td>16.29&lt;sup&gt;b&lt;/sup&gt;</td>
<td>11.58&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10.89&lt;sup&gt;b&lt;/sup&gt;</td>
<td>17.00&lt;sup&gt;b&lt;/sup&gt;</td>
<td>17.90&lt;sup&gt;b&lt;/sup&gt;</td>
<td>***&lt;sup&gt;g&lt;/sup&gt;</td>
</tr>
<tr>
<td>I.LD</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>18.19&lt;sup&gt;c&lt;/sup&gt;</td>
<td>14.24&lt;sup&gt;b&lt;/sup&gt;</td>
<td>12.37&lt;sup&gt;a&lt;/sup&gt;</td>
<td>19.09&lt;sup&gt;c&lt;/sup&gt;</td>
<td>19.92&lt;sup&gt;c&lt;/sup&gt;</td>
<td>***&lt;sup&gt;g&lt;/sup&gt;</td>
</tr>
<tr>
<td>Y</td>
<td>15.61&lt;sup&gt;b&lt;/sup&gt;</td>
<td>11.74&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10.36&lt;sup&gt;a&lt;/sup&gt;</td>
<td>16.66&lt;sup&gt;b&lt;/sup&gt;</td>
<td>17.37&lt;sup&gt;c&lt;/sup&gt;</td>
<td>***&lt;sup&gt;g&lt;/sup&gt;</td>
</tr>
<tr>
<td>Z</td>
<td>15.21&lt;sup&gt;b&lt;/sup&gt;</td>
<td>11.38&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10.23&lt;sup&gt;a&lt;/sup&gt;</td>
<td>16.17&lt;sup&gt;b&lt;/sup&gt;</td>
<td>17.35&lt;sup&gt;c&lt;/sup&gt;</td>
<td>***&lt;sup&gt;g&lt;/sup&gt;</td>
</tr>
<tr>
<td>S.LD</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>18.38&lt;sup&gt;b&lt;/sup&gt;</td>
<td>13.96&lt;sup&gt;a&lt;/sup&gt;</td>
<td>12.15&lt;sup&gt;a&lt;/sup&gt;</td>
<td>22.10&lt;sup&gt;c&lt;/sup&gt;</td>
<td>21.04&lt;sup&gt;c&lt;/sup&gt;</td>
<td>***&lt;sup&gt;g&lt;/sup&gt;</td>
</tr>
<tr>
<td>Y</td>
<td>16.09&lt;sup&gt;b&lt;/sup&gt;</td>
<td>11.95&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10.61&lt;sup&gt;a&lt;/sup&gt;</td>
<td>19.73&lt;sup&gt;c&lt;/sup&gt;</td>
<td>18.65&lt;sup&gt;c&lt;/sup&gt;</td>
<td>***&lt;sup&gt;g&lt;/sup&gt;</td>
</tr>
<tr>
<td>Z</td>
<td>14.41&lt;sup&gt;b&lt;/sup&gt;</td>
<td>10.46&lt;sup&gt;a&lt;/sup&gt;</td>
<td>9.08&lt;sup&gt;a&lt;/sup&gt;</td>
<td>17.27&lt;sup&gt;c&lt;/sup&gt;</td>
<td>17.15&lt;sup&gt;c&lt;/sup&gt;</td>
<td>***&lt;sup&gt;g&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup> 1. Spanish carcasses.
<sup>b</sup> 2. Refrigerated British carcasses.
<sup>c</sup> 3. Frozen–thawed carcasses.
<sup>d</sup> 4. Carcasses of suckling Lacaune.
<sup>e</sup> 5. Carcasses of lambs with the same final feed-lot.
<sup>f</sup> I.TB: Internal measurement in m. Triceps braquialis.
<sup>g</sup> I.LD and S.LD: internal and surface measurements in m. Longissimus dorsi.
<sup>h</sup> P < 0.001***.
<sup>i</sup> P < 0.01**.
<sup>j</sup> P < 0.05*.
<sup>k</sup> n.s. not significant.
<sup>l</sup> Different letters indicate significant differences between the means.

---

Block five: carcasses of lambs with the same final feed-lot (same stable): weaned Lacaune and German Merino.

3.2.1. ANOVA
Triestimulus values $X, Y, Z$ have high significant differences (Table 3) at the three measurement sites. With this analysis it is possible to separate blocks two (refrigerated British carcasses) and three (frozen–thawed carcasses) from the other blocks.

Studying CIELAB coordinates, the five blocks are differentiated ($P < 0.001$) by lightness ($L^*$), above all in LD (internal and surface measurements). In I.TB, carcasses from blocks 2 and 3 are darker than those from blocks 1, 4 and 5. Differences ($P < 0.001$) among blocks can be determined through $a^*$ value at I.TB. Bevilacqua and Zaritzky (1986) showed an inverse relationship between storage-time and color-life, and perhaps this aspect, in frozen–thawed carcasses, besides being these animals older and with different grazing-feeding, can explain the redder meat of these carcasses.

In conclusion, these results suggest that factors such as: final feeding, frozen–thawed process, ageing, and particularly the age may explain these differences.

3.2.2. Discriminant analysis
As mentioned above Section 3.1.2 (discriminant analysis by groups), the best discrimination was obtained considering the three measurement sites, and when all the variables are taken. In this way, the percentage is higher than the one that has been obtained when the animals are grouped by groups (94.2 vs 84.9%).

Considering the six variables at the three measurement sites (Table 4), we can confirm that the Spanish carcasses are grouped, by this statistical method, into their group with the exception of three animals (that are out of the diagonal, as we can see in this Table). All the refrigerated carcasses are in its group. Two carcasses of the suckling Lacaunes group are placed in the Spanish carcasses group. And finally, animals with the same feed-lot are also accurately grouped.

3.2.3. Principal components analysis
After the application of this analysis to the colour variables at the three measurement sites, the best results are obtained with $X$, $Y$ and $Z$ variables (tristimulus values).

In this analysis, the first factor of principal components (lineal combinations of variables) explains a large

Table 4
Discriminant analysis frequencies. Classification of carcasses by five blocks: assigned (columns) against real data (rows)$^a$

<table>
<thead>
<tr>
<th></th>
<th>1$^b$</th>
<th>2$^c$</th>
<th>3$^d$</th>
<th>4$^e$</th>
<th>5$^f$</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>38</td>
<td>8</td>
<td>2</td>
<td>1</td>
<td>41</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>15</td>
<td>5</td>
<td>1</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>15</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>16</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td>86</td>
</tr>
<tr>
<td>Total</td>
<td>40</td>
<td>8</td>
<td>15</td>
<td>7</td>
<td>16</td>
<td>86</td>
</tr>
</tbody>
</table>

$^a$ Variables: $X, Y, Z, L^*, a^*, b^*$, in I.TB (internal measurement in m. Triceps braquialis). S.LD and I.LD (surface and internal measurements in m. Longissimus dorsi).

$^b$ 1. Spanish carcasses.
$^c$ 2. Refrigerated British carcasses.
$^f$ 5. Carcasses of lambs with the same final feed-lot.

Table 5
Weights of each variable in the two factors of principal component analysis

<table>
<thead>
<tr>
<th></th>
<th>Factor 1</th>
<th>Factor 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.TBa</td>
<td>0.408</td>
<td>0.902</td>
</tr>
<tr>
<td>Y</td>
<td>0.437</td>
<td>0.894</td>
</tr>
<tr>
<td>Z</td>
<td>0.494</td>
<td>0.858</td>
</tr>
<tr>
<td>I.LDb</td>
<td>0.775</td>
<td>0.551</td>
</tr>
<tr>
<td>Y</td>
<td>0.770</td>
<td>0.571</td>
</tr>
<tr>
<td>Z</td>
<td>0.756</td>
<td>0.595</td>
</tr>
<tr>
<td>S.LDb</td>
<td>0.905</td>
<td>0.375</td>
</tr>
<tr>
<td>Y</td>
<td>0.897</td>
<td>0.392</td>
</tr>
<tr>
<td>Z</td>
<td>0.863</td>
<td>0.448</td>
</tr>
</tbody>
</table>

$^a$ I.TB.: Internal measurements in m. Triceps braquialis.
$^b$ I.LD and S.LD: Internal and surface measurements in m. Longissimus dorsi.
part of the variance (87.64%). However, we decided to take two factors in order to improve the result and to make a graphic representation.

When the two factors are rotated, 95.15% of the variation is explained (52.61% for the first factor and 42.54% for the second).

The contribution of the colourimetric parameters measured in I.D. (both I.LD and S.LD) is more important in the first factor (Table 5), while the parameters measured in Triceps (I.TB) are more relevant in the second factor.

Factor one is represented versus factor two in order to see the discriminant power of these factors (see Fig. 2). Refrigerated carcasses (B) appear between fresh (A, D and E) and frozen–thawed (C) carcasses. Animals with the same feed-lot are mixed with fresh carcasses, but are accurately grouped in the upper zone of the graph, close to the carcasses of the suckling animal group.

3.2.4. Cluster analysis

As can be observed in Fig. 3, the closeness between these groups (average values in Table 3) is confirmed. It supports, again, explanations given in previous analyses. Animals from blocks four and five are close; as are the frozen and refrigerated carcasses. Finally, Spanish carcasses are placed close to those of the suckling and the same final feed-lot animals.

4. Conclusions

1. Discrimination by colourimetric variables can be an effective method to distinguish some origins.
2. Discrimination by “breed” in this paper is acceptable, while differences among them exist.
3. Some animals that are incorrectly classified (according to the different analyses) appear in another group, with similarities in carcasses storage or type of final breeding period.
4. If animals are grouped according to final conditions of feeding and storage, a high discrimination is obtained (94.2%), suggesting these features influence meat colour.

Acknowledgements

The authors wish to thank the Animal Production Department of Veterinary Faculty in Zaragoza (Spain) for their technical assistance.

References


SYSTAT. 5.0 (1992). SYSTAT Inc.